

Kimio KATO*: **Studies on the geographical distribution
of *Allomyces* in Japan****

加藤 君 雄*: 日本における *Allomyces* 属菌の地理的分布**

Since *Allomyces arbuscula*, one of aquatic fungi belonging to Blastocladiaceae, was isolated from humid soil in India¹⁾, a number of species have been added to the genus by many investigators at various districts in several countries. Now, the genus *Allomyces* includes 10 species with varieties, all of which are known to be saprophytic and terrestrial. These species distribute in tropical or temperate zones of all over the world.

In Japan, only a few contributions have been published on the classification and morphology of the genus by Indoh⁶⁾, and the present author⁷⁾ noted on the distribution in northern part of Japan. The present paper deals with a complete description and distribution of *Allomyces* species hitherto found in Japan, with special regard to the northern limit of their distribution.

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Enumeration of the species

I a. *Allomyces arbuscula* Butler var. *arbuscula*. (Fig. 1)

This fungus was described by Butler¹⁾ in 1911 from Pusa in India. Since then it was recorded from various districts of the world by many investigators such as Barret²⁾, Coker³⁾, Wolf⁴⁾ and Emerson⁵⁾. It seems a typical cosmopolitan. In Japan, it distributes abundantly and widely from Miyako-jima (Okinawa) to Oodate (Akita Prefecture).

Loc. coll. *Okinawa*: Miyako (Aug. 11. 1956). *Korea*: Eedo (Sep. 10. 1940), Syuhure (Sep. 15. 1940). *Kagoshima*: Hayato (Aug. 11. 1954), Kagoshima (Aug. 13. 1954). *Kumamoto*: Uto (Aug. 9. 1954), Yatsushiro (Aug. 9. 1954). *Saga*:

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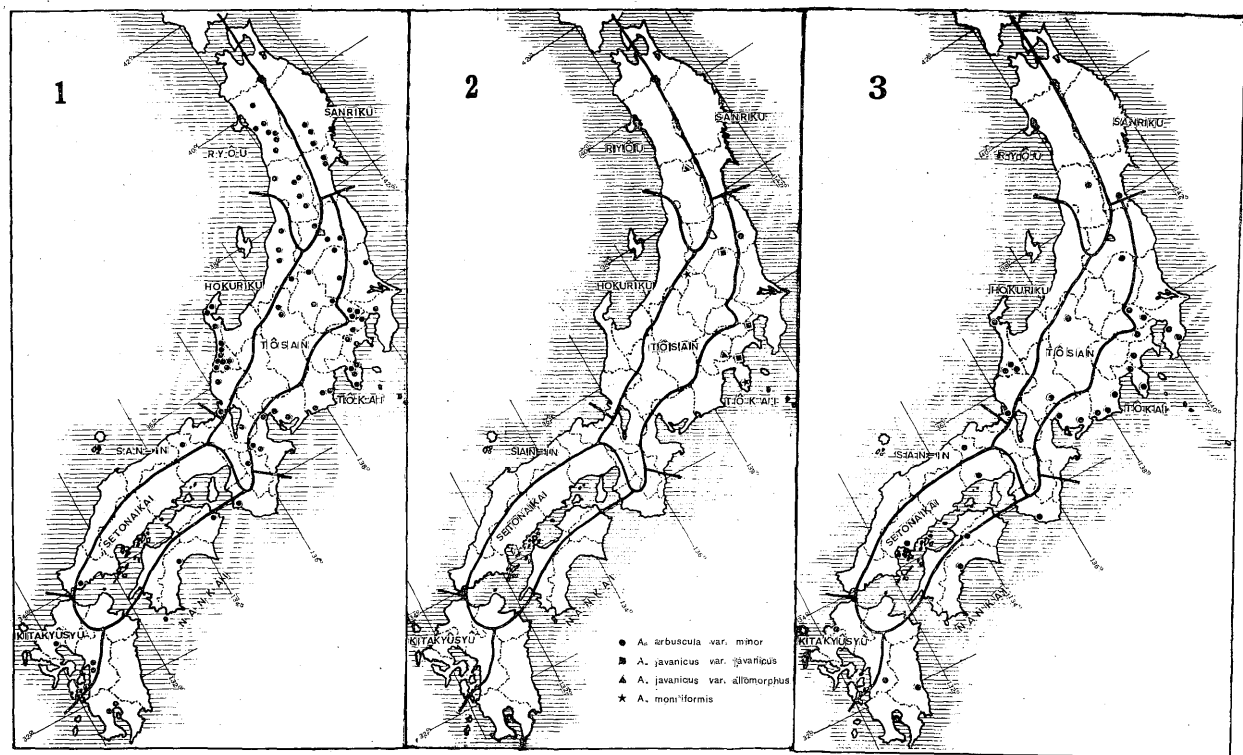


Fig. 1-3. Distribution maps of *Allomyces arbuscula* (1), *A. arbuscula* var. *minor* (2), *A. javanicus* (2), *A. javanicus* var. *allomorphus* (2), *A. moniliformis* (2) and *A. javanicus* var. *japonensis* (3) in Japan.

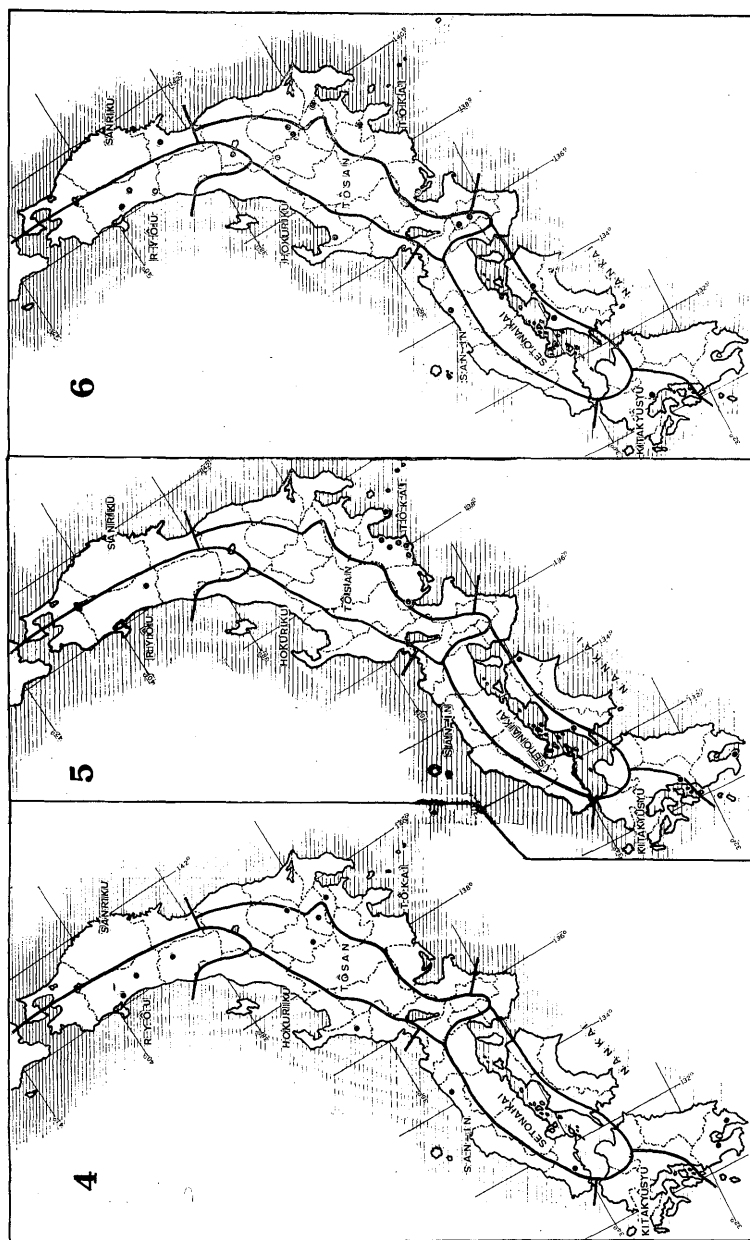


Fig. 4-6. Distribution maps of *Allomyces cystogenus* (4), *A. cystogenus* var. *elongatus* (5) and *A. anomalus* (6) in Japan.

Saga (Aug. 8. 1954). Kochi: Kochi (Aug. 13. 1958). Tokushima: (Aug. 10. 1958). Yamaguchi: Onoda (Oct. 3. 1959). Hyogo: Tateya (Jul. 7. 1939). Wakayama: Nankai (Jul. 26. 1959). Nara: Miwa (Sep. 10. 1939). Mie: Kuwana (Oct. 25. 1940), Kusuda (Aug. 19. 1942), Kashiwara (May 18. 1954). Aichi: Nagoya (Oct. 25. 1940), Okazaki (Oct. 3. 1956). Shizuoka: Hamamatsu (Apr. 15. 1940), Nirayama (Aug. 9. 1942), Atami (App. 19. 1940), Ochito (Aug. 9. 1942), Hatsukura (Oct. 1. 1957), Yoshida (Oct. 1. 1957), Rendaiji (Jun. 15. 1957). Shiga: Giou (Aug. 14. 1942). Fukui: Tsuruga (May 20. 1954), Fukui (Oct. 6. 1956). Ishikawa: Tyokushi (Aug. 9. 1941), Wajima (Jul. 31. 1942), Tsurugiji (Aug. 1. 1942), Hagui (Aug. 3. 1942), Higashi-Kanazawa (Aug. 4. 1942), Ataka (Aug. 5. 1942), Awazu (Aug. 6. 1942), Komatsu (Aug. 13. 1953), Tsubata (Jul. 27. 1953). Yamashiro (Aug. 11. 1953), Oosugiya (Aug. 11. 1953). Nagano: Nagano (Aug. 20. 1939), Shinonoi (Aug. 21. 1939). Niigata: Ishiuchi (Jul. 29. 1942), Takiya (Oct. 2. 1957), Honai (Nov. 2. 1957), Nakaura (Nov. 3. 1957). Tokyo: Zenpukuji (May 30. 1942), Itabashi (Aug. 18. 1947). Kanagawa: Yose (Oct. 2. 1958), Kokufu (Oct. 12. 1958). Chiba: Funabashi (Jun. 25. 1946). Saitama: Oomiya (Apr. 25. 1958), Doai (May 23. 1947), Yono (Oct. 6. 1960). Tochigi: Nasu (Jul. 12. 1941), Hooshakuji (Aug. 10. 1954). Gunma: Rokugo (Aug. 19. 1942), Akima (Aug. 13. 1942), Oze (Jul. 5. 1950). Ibaraki: Taga (Apr. 17. 1953). Fukushima: Niwasaka (Nov. 7. 1953), Sukagawa (Apr. 3. 1955), Ishikawa (Apr. 4. 1955). Miyagi: Kogota (Sep. 6. 1955), Semine (Sep. 7. 1955). Yamagata: Yokoyama (May 15. 1947), Tateoka (May 26. 1947), Kitayamagata (May 23. 1956), Tsuruoka (Jul. 15. 1955), Funagata (May 25. 1960)*. Iwate: Kitakami (Aug. 21. 1950), Mizusawa (Oct. 5. 1960), Ichinoseki (Oct. 5. 1960). Akita: Akita (Jun. 2. 1952), Taihei (May 15. 1952), Ugosakai (Feb. 20. 1952), Kariwano (May 20. 1952), Jinguji (May 23. 1952), Yasawagi (Oct. 5. 1952), Oodate (Oct. 20. 1957).

1 b. *Allomyces arbuscula* Butler var. *minor* Emerson. (Fig. 2)

Emerson⁵⁾ proposed var. *minor* for the fungus isolated from North Carolina by its minor size of chlamydocytes. The author isolated once a specimen which has always very minor chlamydocytes (20-30 μ in breadth) from Takine (Fukushima Pref.).

Loc. coll. Fukushima: Takine (Apr. 5. 1955).

2 a. *Allomyces javanicus* Kniep var. *javanicus*. (Fig. 2)

* This strain differs a little in its life cycle from var. *arbuscula*. Details will be published in future.

Tab. 1. Detection of each taxon of *Allomyces* and their dominancy
(showing in %) in each climatic zones.

Climatic zone \ Taxon	<i>A. arbuscula</i>	<i>A. arbuscula</i> var. <i>minor</i>	<i>A. javanicus</i>	<i>A. javanicus</i> var. <i>japonensis</i>	<i>A. javanicus</i> var.	<i>A. allomorphus</i>	<i>A. monili-</i> <i>formis</i>	<i>A. cystogenus</i>	<i>A. cystogenus</i> var. <i>elongatus</i>	<i>A. anomalous</i>	
Ryôu	13 (56.5)			1 (4.4)	1 (4.4)			3 (13.0)	1 (4.4)	4 (17.3)	23
Sanriku	5 (71.4)			1 (14.3)						1 (14.3)	7
Hokuriku	16 (69.6)			5 (21.8)				1 (4.3)		1 (4.3)	23
Tôsan	12 (48.0)		1 (4.0)	3 (12.0)			1 (4.0)	3 (12.0)		5 (20.0)	25
Tôkai	21 (41.1)	1 (2.0)	2 (3.9)	13 (25.5)	1 (2.0)	1 (2.0)	2 (3.9)	7 (13.7)		3 (5.9)	51
Sanin	1 (25.0)			1 (25.1)				1 (25.0)		1 (25.0)	4
Setonaikai	1 (16.7)			2 (33.2)				1 (16.7)	1 (16.7)	1 (16.7)	6
Nankai	5 (31.1)			5 (31.1)				2 (12.6)	2 (12.6)	2 (12.6)	16
Kitakyûsyû	3 (49.9)			1 (16.7)					1 (16.7)	1 (16.7)	6
Okinawa	1 (50.0)									1 (50.0)	2
Southern Korea	2 (50.0)									2 (50.0)	4
Total	80 (47.9)	1 (0.6)	3 (1.8)	32 (19.2)	2 (1.2)	2 (1.2)		13 (7.8)	12 (7.1)	22 (16.7)	167

This fungus was originally isolated by Kniep¹⁰⁾ from Java and studied the anisogamous planogametic reproduction of the genus for the first time. Emerson⁴⁾ collected the fungus in North America, Middle America, Africa, India, Burma, Fiji isl. etc., but the frequency of the appearances is rather few. In Japan, it is found also very rarely, only at three localities in Tôkai and Tôsan areas.

Loc. coll. *Kanagawa*: Yumototaira (May 10. 1942). *Tokyo*: Hongo (Jun. 30. 1942). *Tochigi*: Nasu (Jun. 12. 1941).

2 b. *Allomyces javanicus* Kniep var. *japonensis* Indoh. (Fig. 3)

This fungus was originally isolated by Indoh from Shinonoi (Nagano Pref.). It differs from var. *javanicus* in its larger size of male and female gametangia. This variety is commonly found in Japan from Miyazaki (Miyazaki Pref.) to Obanazawa (Yamagata Pref.), but seems to be densely distributed rather in the southern part than in the northeastern part of Japan. Emerson⁵⁾ reported this variety from North America under the name of var. *macrognus*.

Loc. coll. *Miyazaki*: Miyazaki (Aug. 15. 1954). *Kumamoto*: Hitoyoshi (Aug. 10. 1954). *Fukuoka*: Fukuoka (Aug. 7. 1954). *Tokushima*: Samaji (Aug. 11. 1958). *Kochi*: Hirooka (Aug. 23. 1940). *Hiroshima*: Hiroshima (Oct. 5. 1959). *Hyogo*: Yagi (Sep. 30. 1941), Tateya (Jul. 7. 1939). *Wakayama*: Gobou (Jul. 26. 1959). *Gifu*: Unuma (Sep. 10. 1940). *Aichi*: Nagoya (Sep. 8. 1940), Toyohashi (Oct. 2. 1956). *Shizuoka*: Hamamatsu (Apr. 14. 1940), Hamanako (Apr. 18. 1940), Mishima (May 28. 1941), Yoshida (Oct. 1. 1957), Shimogamo (Jun. 16. 1957). *Fukui*: Tsuruga (May 20. 1954). *Ishikawa*: Morooka (Sep. 15. 1941), Tsurugiji (Oct. 17. 1941), Oosugiya (Aug. 11. 1953), Komatsu (Aug. 13. 1953). *Nagano*: Shinonoi (Aug. 21. 1939). *Kanagawa*: Yamakita (Oct. 21. 1958). *Tokyo*: Kokubunji (Jun. 19. 1957). *Chiba*: Katsuura (Jul. 24. 1940), Ghiba (Jun. 24. 1966). *Saitama*: Oogoe (Aug. 8. 1941), Yono (Oct. 6. 1960). *Tochigi*: Kuroiso (Apr. 13. 1954). *Miyagi*: Ookawara (May 23. 1958). *Yamagata*: Obanazawa (Apr. 10. 1947).

2 c. *Allomyces javanicus* Kniep var. *allomorphus* Indoh. (Fig. 2)

This fungus was isolated by Moriyama in 1948 from the soil of paddy field near Lake Yamanaka and newly named by Indoh⁷⁾, distinguishing from var. *javanicus* by its variable shape and arrangement of male and female gametangia. The author also isolated it from Ootaki, northern part of Yamagata Pref.

Loc. coll. *Yamanashi*: Yamanaka (Aug. 16. 1948). *Yamagata*: Ootaki (May 22. 1958).

3 *Allomyces moniliformis* Coker et Braxton. (Fig. 2)

Tab. 2. Frequency of detection of *Allomyces* in samples collected from various climatic zones in Japan.

Climatic zone	Region	Number of collected soil samples	Number of soil samples from which <i>Allomyces</i> detected	Frequency of detection of <i>Allomyces</i> (%)
Ryôu	Akita	473	12	2.5
	Yamagata	304	8	2.6
Sanriku	Miyagi	108	3	2.8
Hokuriku	Niigata	115	3	2.6
Tôsan	Fukushima	177	5	2.8
Tôkai	Shizuoka	53	2	3.8
	Wakayama	50	2	4.0
Setonaikai	Yamaguchi	30	1	3.3
Nankai	Kochi	25	1	4.0
	Kagoshima	52	2	3.9
Kitakyûsyû	Kumamoto	96	4	4.2
Okinawa	Miyako	33	1	3.0

This fungus was isolated by Coker and Braxton³⁾ from North Carolina for the first time. And later Wolf¹¹⁾ and Emerson⁵⁾ found it from Mexico. This species is similar to *A. cystogenus* in the zoospores discharged from chlamydocysts, developing into minute gametophytes, but differs from it in having rhombic chlamydocysts. In Japan, it was isolated only at two localities in Tôkai and Tôsan areas.

Loc. coll. *Shizuoka*: Shimoda (Jun. 3. 1947). *Niigata*: Ishiuchi (Aug. 28. 1947).
4 a. *Allomyces cystogenus* Emerson var. *cystogenus*. (Fig. 4)

Emerson isolated this fungus from Arizona. He investigated the life cycle and established the subgenus *Cystogenus*. This species was described by Indoh⁹⁾ under the name *A. neo-moniliformis* based upon his isolations from Oosumi (Kagoshima Pref.) and Koganei (Tokyo). It was also found from Burma, China, Venezuela and North America by Emerson⁵⁾.

Loc. coll. *Kagoshima*: Oosumi (Jun. 2. 1939), Kagoshima (Apr. 1. 1940). *Yamaguchi*: Higashi-Atsuhô (Nov. 30. 1941). *Tottori*: Tottori (Aug. 6. 1957). *Ishikawa*: Komatsu (Aug. 13. 1953). *Tokyo*: Koganei (Oct. 2. 1939), Hachizyo-jima

(Aug. 15. 1939). *Saitama*: Ogose (Mar. 31. 1942). *Gunma*: Takada (Nov. 4. 1957). *Tochigi*: Ishibashi (May 12. 1940). *Yamagata*: Shinzyo (Jul. 19. 1955). *Akita*: Akita (May 10. 1951), Naraoka (Oct. 14. 1957).

4 b. *Allomyces cystogenus* Emerson var. *elongatus* Emerson. (Fig. 5)

This fungus was isolated from North America by Emerson, and it differs from var. *cystogenus* in its elongate-elliptic chlamydocysts. Localities of this variety is limited mostly in the central part of Tôkai area except a single case at Akita Prefecture.

Loc. coll. *Kagoshima*: Yamakawa (Oct. 12. 1958). *Kumamoto*: Yatsushiro (Aug. 11. 1954). *Ehime*: Matsuyama (Sep. 2. 1959). *Tokushima*: Tokushima (Aug. 10. 1958). *Shizuoka*: Sato (Aug. 16. 1940), Kakegawa (Aug. 12. 1940), Shizuoka (May 17. 1941), Hamamatsu (Jun. 22. 1941), Yoshida (Oct. 1. 1957), Sagara (Oct. 4. 1957). *Aichi*: Ichinomiya (Aug. 28. 1941). *Akita*: Mitsuseki (Oct. 2. 1955).

5. *Allomyces anomalus* Emerson. (Fig. 6)

This fungus was recorded from Texas, India, China and Mexico by Emerson⁵⁾ and Wolf¹¹⁾. Chlamydocysts of this fungus are quite similar to those of *A. arbuscula* and *A. javanicus* but no asexual mycelia has yet been observed. Indoh⁶⁾ reported such a fungus from Okinawa as *A. sp.* And later, a number of specimens of the fungus were isolated from various districts in Japan.

Loc. coll. *Okinawa*: Shimajiri (Jun. 25. 1939). *Korea*: Suigen (Sep. 10. 1940), Ryuzan (Sep. 10. 1940). *Kumamoto*: Arao (Sep. 18. 1940). *Ehime*: Tokuda (Aug. 13. 1941). *Kochi*: Aki (Aug. 21. 1940). *Tokushima*: Samaji (Sep. 10. 1940). *Tottori*: Tottori (Aug. 6. 1957). *Nara*: Ikomayama (Aug. 12. 1941), Hashio (Aug. 26. 1941). *Aichi*: Okada (Jul. 24. 1940). *Toyama*: Takaoka (Oct. 29. 1955). *Shizuoka*: Gotenba (Jul. 10. 1941). *Tokyo*: Koiwa (Jul. 16. 1941). *Tochigi*: Nagusa (Aug. 21. 1940), Tanuma (Aug. 28. 1940). *Gunma*: Shimotashiro (Aug. 2. 1952). *Fukushima*: Kitakata (Sep. 20. 1959). *Miyagi*: Furukawa (Aug. 26. 1961). *Akita*: Oomagari (Oct. 19. 1952), Akita (Jun. 10. 1958), Yashima (Aug. 27. 1961).

Discussion

In Japan we can find the following 9 taxa of *Allomyces*; *A. arbuscula*, *A. arbuscula* var. *minor*, *A. javanicus*, *A. javanicus* var. *japonensis*, *A. javanicus* var. *allomorphus*, *A. moniliformis*, *A. cystogenus*, *A. cystogenus* var. *elongatus*

Table 3. Climatic factors at the localities from where
Allomyces were isolated.

Locality	Mean atmospheric temperature (°C)			Rainfall (mm) annual
	minimum month	maximum month	annual	
Oodate	-2.4	24.6	10.5	1581
Akita	-1.6	24.4	10.5	1786
Yamagata	-2.0	24.6	10.7	1250
Sendai	-0.2	23.9	11.1	1216
Fukushima	0.2	25.2	12.0	1145
Mito	1.7	24.8	12.7	1395
Tokyo	3.2	26.4	14.3	1568
Hachijojima	9.9	26.4	17.6	3252
Nagoya	-2.0	24.7	11.0	976
Shizuoka	5.2	26.1	15.4	2278
Nagano	2.5	26.6	14.2	1513
Kanazawa	2.1	26.0	13.3	2486
Fukui	1.9	26.5	13.6	2374
Wakayama	4.9	27.0	15.3	1386
Tottori	3.7	26.9	14.6	1527
Tokushima	4.6	26.6	15.2	1568
Fukuoka	4.8	26.8	15.1	1596
Kumamoto	4.3	27.0	15.5	1757
Miyazaki	6.7	26.8	16.6	2526
Kagoshima	6.4	27.1	16.6	2170

No data of *Allomyces* in the following localities.

Hakodate	-3.4	22.1	8.5	1202
Aomori	-3.0	23.0	9.2	1425
Morioka	-3.3	23.2	9.3	1205

and *A. anomalus*. Figs. 1-6 show roughly the distribution of each taxon in Japan with the climatic zones referred in this article, and Tab. 1 indicates their occurrence and dominancy (showing in %) in various climatic zones. These data tell us that *A. arbuscula* appears most abundant and distributes widely in various zones and *A. javanicus* var. *japonensis*, *A. anomalus*, *A. cystogenus* and *A. cystogenus* var. *elongatus* follow to it. It is interesting that the other 4 taxa

are rare and exhibit different patterns of geographical distribution. That is, *A. cystogenus* var. *elongatus* distributes in the warm temperate zones of the pacific side of Japan, while *A. javanicus* var. *allomorphus* and *A. arbuscula* var. *minor* in the cold temperate zones in the inland region of the northern part of Honsyu. *A. javanicus* var. *allomorphus*, an endemic one, was isolated only from the cold temperate zones of the mountain regions. Tab. 2 indicates the frequency of detection of *Allomyces* at various climatic zones. From the table, it is known that the southern Kyusyu and the southern districts of the pacific side of Honsyu have higher frequencies, while the northern part of Honsyu have a lower frequency. It is a noticeable fact that the frequency of detection in Akita Prefecture of *Allomyces* shows the lowest value, 2.5 % and no *Allomyces* has yet been isolated from Aomori Prefecture and Hokkaido in spite of examinations of many samples. The northern boundary of the habitat of *Allomyces* in Japan is limited in Akita Prefecture.

Among the environmental factors affecting the geographical distribution of *Allomyces*, temperature is most important. The habitat of *Allomyces* in Japan is generally paddy fields where the environmental conditions, outside of temperature, are almost same in every regions of the country. As shown in Tab. 4, the annual mean atmospheric temperature of the regions from where *Allomyces* was isolated, is higher than 10.5°C, which is the annual mean atmospheric temperature at Oodate, the northern boundary of habitat of *Allomyces* in Japan. It seems that the author's observation⁸⁾ of no growth of mycelium of *Allomyces* below 10°C supports the above mentioned distribution. It cannot be accepted that the rainfall effects on the distribution of the genus (see also Tab. 3).

Emerson⁵⁾ reported that the northern limits of the distribution of *Allomyces* are Montedor (Portugal) in Europe, and Ithaca and the suburbs of New York in North America. These regions are situated in latitude about 40°N, which corresponds to the latitude at Oodate in Japan. It is interesting that the northernmost limit of the fungi both in Japan and North America corresponds with the northernmost region of Köppen's humidtemperate climatic zone to which a special attention has been paid from a point of geographical view of the higher plants.

Summary

The geographical distribution of *Allomyces* in Japan was investigated. The most abundant and widely distributed species is *A. arbuscula* and the com-

monly found species is *A. javanicus* var. *japonensis*. *Allomyces* species are found abundantly in the southern part of Honsyu. The density of the distribution decreases gradually toward the north. The northern limit of the distribution is Oodate (Akita Pref.), where the latitude (ca 40°N) agrees with that of the limit of the fungus in North America and Europe. The annual mean atmospheric temperature of the regions, where *Allomyces* species are found, is higher than 10.5°C.

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摘 要

熱帯要素の一員である *Allomyces* が気候的要因の変化に富む本邦にどのように分布するか、そのフロラを明らかにするとともに、分布の北限界について検討した。本邦で分布範囲が最も広く、且つ多産するのは *Allomyces arbuscula* でこれに *A. javanicus* var. *japonensis* と *A. anomalus* が次ぐが、*A. cystogenus*, *A. cystogenus* var. *elongatus* は一般に少く、*A. javanicus*, *A. javanicus* var. *allomorphus*, *A. arbuscula* var. *minor*, *A. moniliformis* がまれに産する。種類によっては多少分布域を異にするが、分布密度とその勾配を菌株の分離頻度から検討すると、九州南部が最も高く、南海と東海南部がこれに次ぎ、北陸、両羽地区と北上するに及んで低くなり、大館を *A. arbuscula* の分布の終点としてこれより以北からは分離されない。分布の制限因子は土性的なものより広域気候的要因にあるものと思われる。本邦では北限産地にあたる大館の年平均気温 10.5°C を限度として、いづれの産地もこれより高温線内にある。欧米および本邦と本属分布の北限界は地理的位置では北緯 40 度付近に一致し、この地点がまた Köppen の温暖高温気候区の北方の境界にあたる点でも本邦と北米の北限産地は一致する。

□病床にあられた桜井久一博士は昭和38年4月30日薬石効なく永眠された。74才。博士の莫大な蘚苔類の標本は東京都立大学牧野標本館に収められることになった。